Photonic Doppler Pressure Gauge (PDPG)

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Why ***another*** gauge ?

- Original Motivation: We wish to measure *in situ* pressure at multiple locations in reactive granular materials.

- Conventional gauge technologies appeared to be:
- Limited in bandwidth
- Vulnerable to EMI
- Too expensive for sacrificial use

- Last year, the boundaries of PDV technology[1] were pushed to obtain high resolution projectile velocity and acceleration measurements[2] in IAT's 2-stage gas gun launcher, and these measurements allowed us to identify theoretical features of pressure measurements[3] - formerly not possible.

- The new PDPG further exploits the robust nature, accuracy, high resolution, and wide temporal & velocity features of the PDV process.

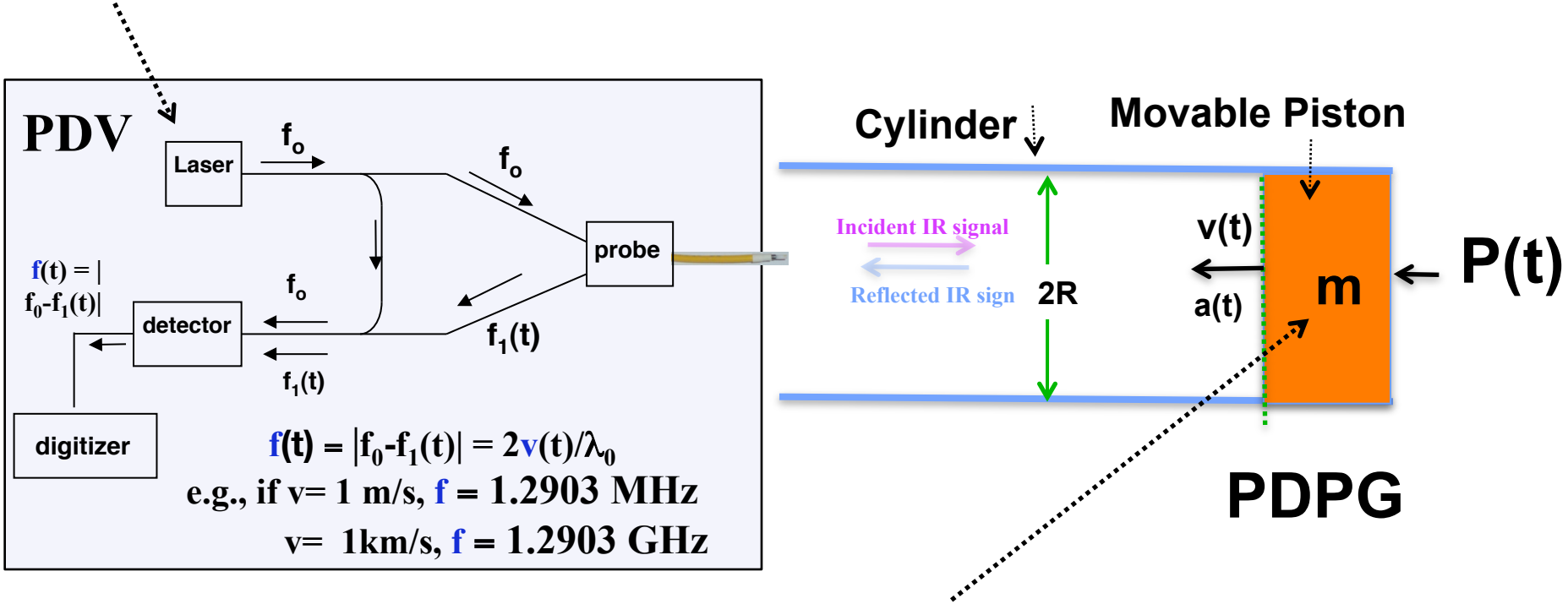
1. "Compact system for high-speed velocimetry using heterodyne techniques," O. Strand, D. Goosman, C. Martinez, and C. Whitworth, Rev. Sci. Inst. 77, 83108, 2006.

2 "High-Resolution Projectile Velocity And Acceleration Measurement Using Photonic Doppler Velocimetry," Scott J. Levinson, Sikhanda Satapathy, Shock Compression of Condensed Matter, pp. 585-588, AIP Conf. Proc. 1195, Issue 1, 2009.

3 "Comparison of Theory and Measurements of a Two-Stage Light-Gas Gun," S. Levinson, D. Berry, B. Pedersen, and S. Bless, Shock Compression of Condensed Matter, pp. 623-626, AIP Conf. Proc. 1195, Issue 1 , 2009.

Conceptual Design for a PDPG

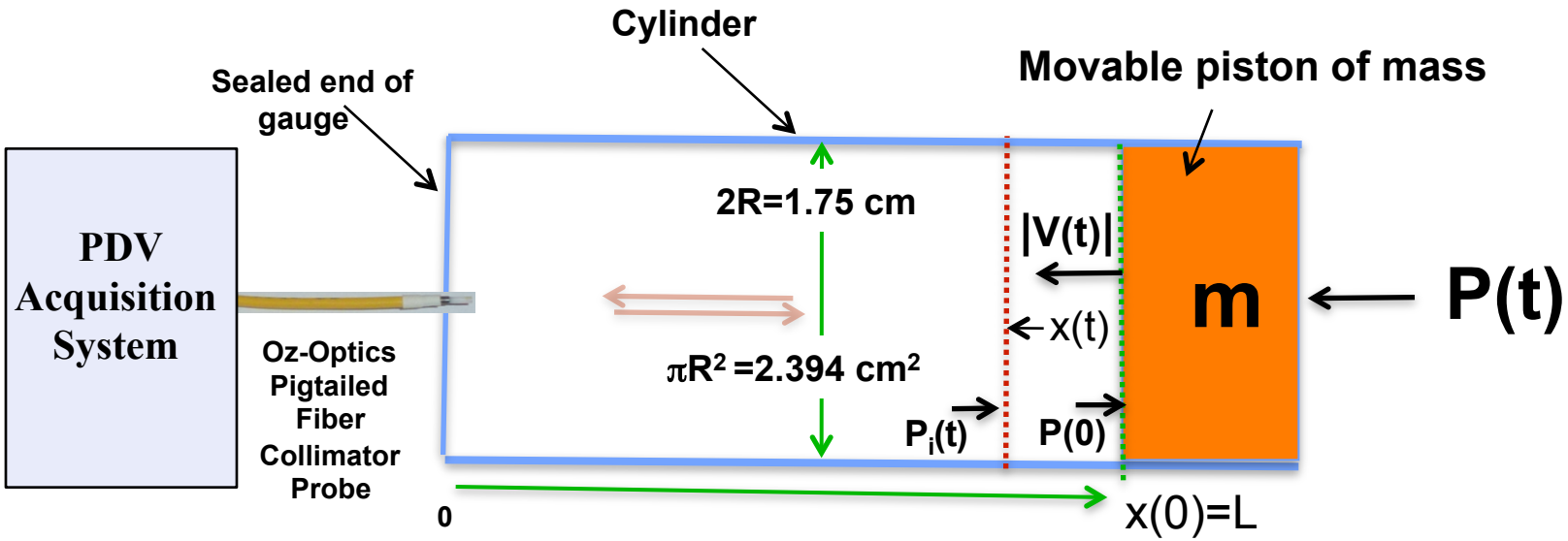
PDV determines velocity v(t) by measuring beat frequency f(t) after "mixing" un-shifted incident laser signal (frequency $f_0 = c/\lambda_0$ =193.414489 THz) with Doppler-shifted, reflected signal (f_1).



1. Pressure P(t) is applied to a movable piston of mass m inside cylinder of radius R.
2. Piston is accelerated: $a(t) = \frac{dv(t)}{dt} = \pi R^2 P(t)/m$
3. Acceleration a(t) is numerical derivative of accurate, highly resolved, PDV measurement of $v(t) = \lambda_0 f(t)/2$.

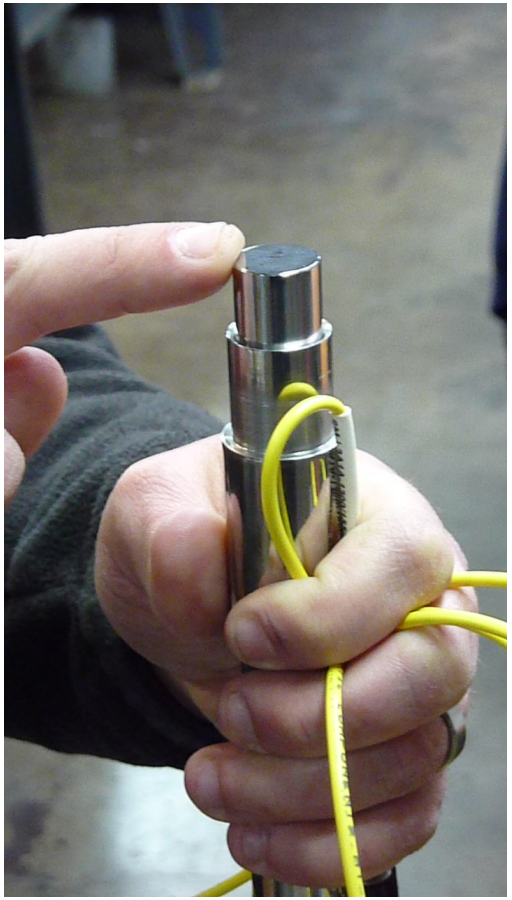
Testing a PDPG Prototype

Objective: measure $P(t) = m*a(t)/(\pi R^2)$ by accurately measuring piston velocity

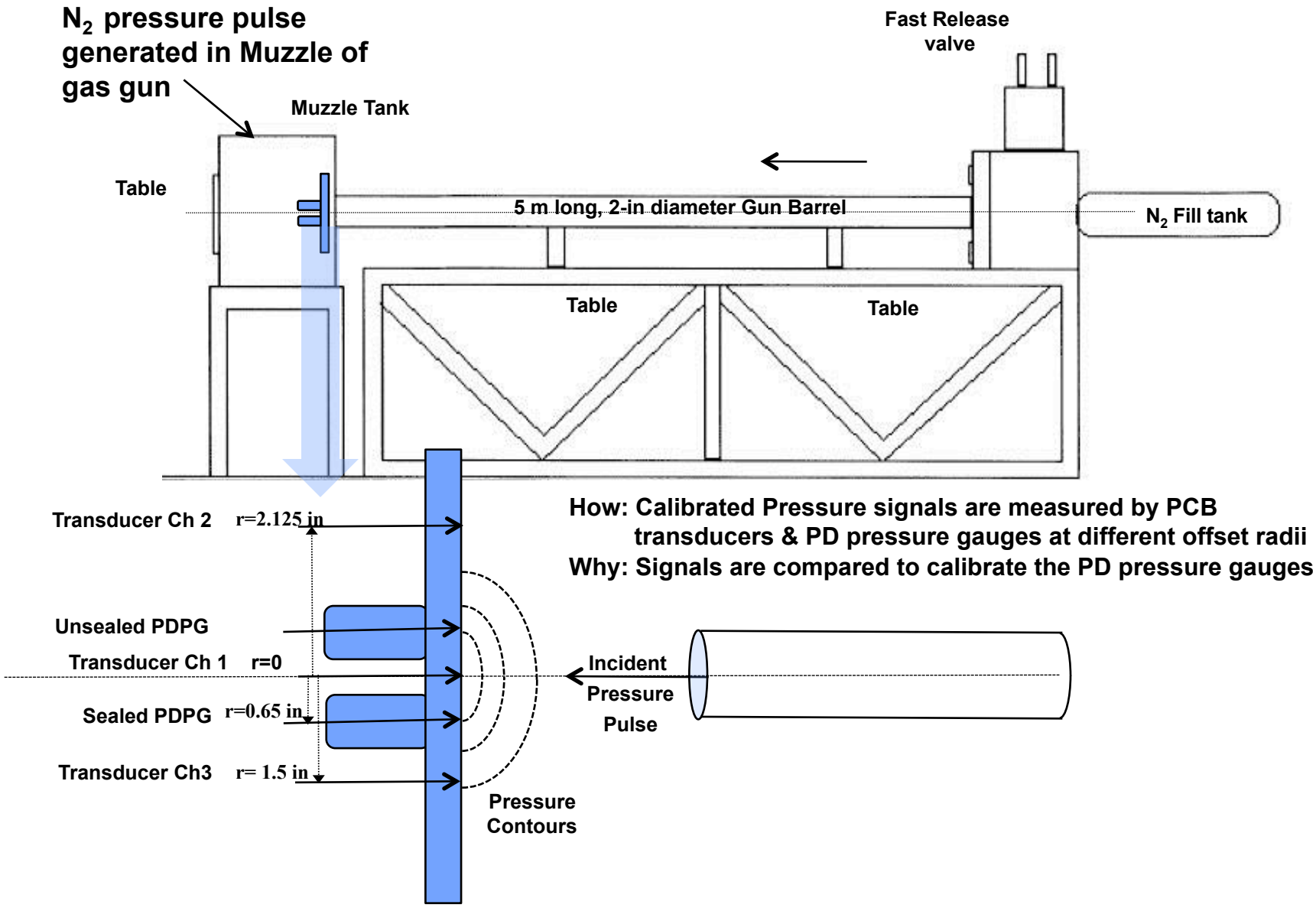


PD Pressure Gauge Prototype and Piston movement

We used inexpensive "paint-ball" barrels & aluminum and stainless steel pistons (πR^2=2.39 cm^2)



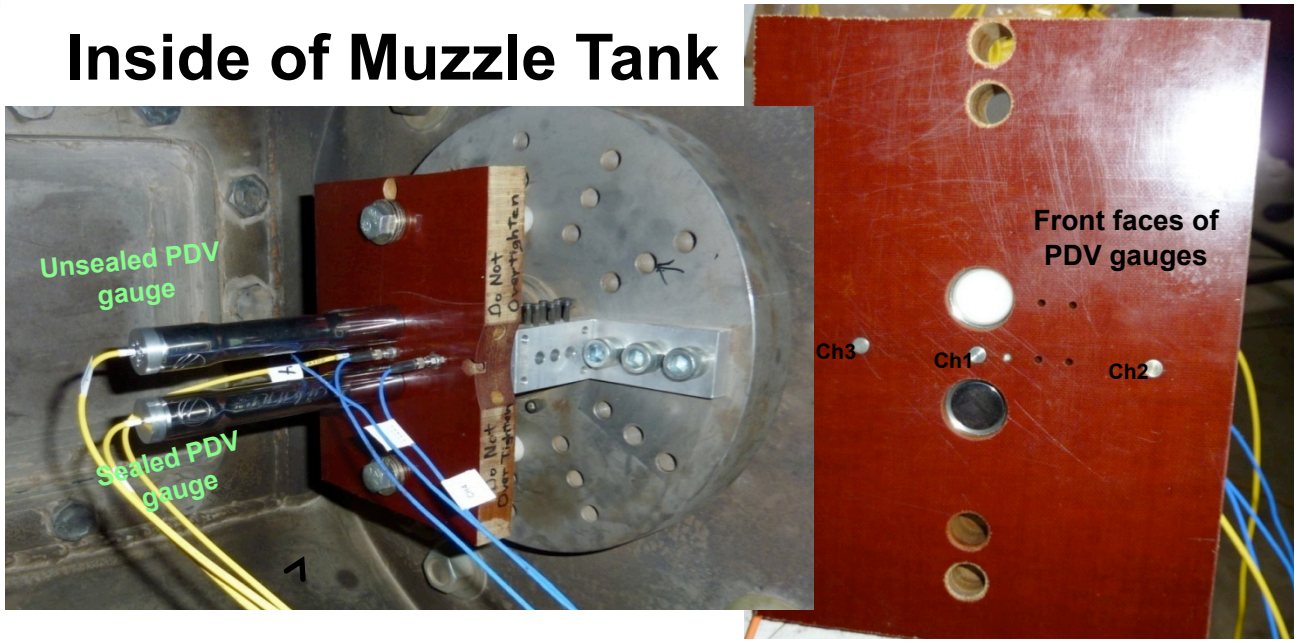
We used a gas gun to generate calibration pressure pulses



How: Calibrated Pressure signals are measured by PCB transducers & PD pressure gauges at different offset radii

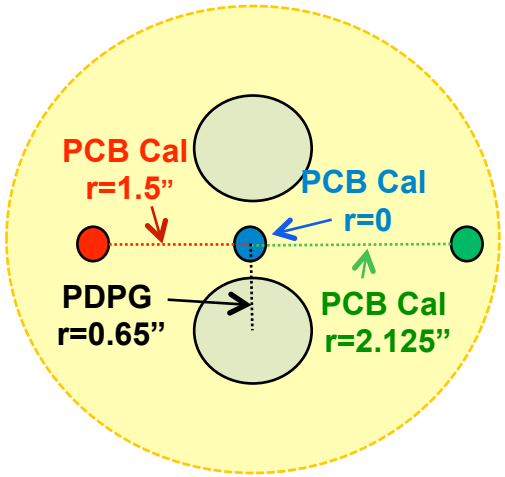
Why: Signals are compared to calibrate the PD pressure gauges

Inside of Muzzle Tank



Test 1: Back of *Unsealed* PD gauge Has holes for venting

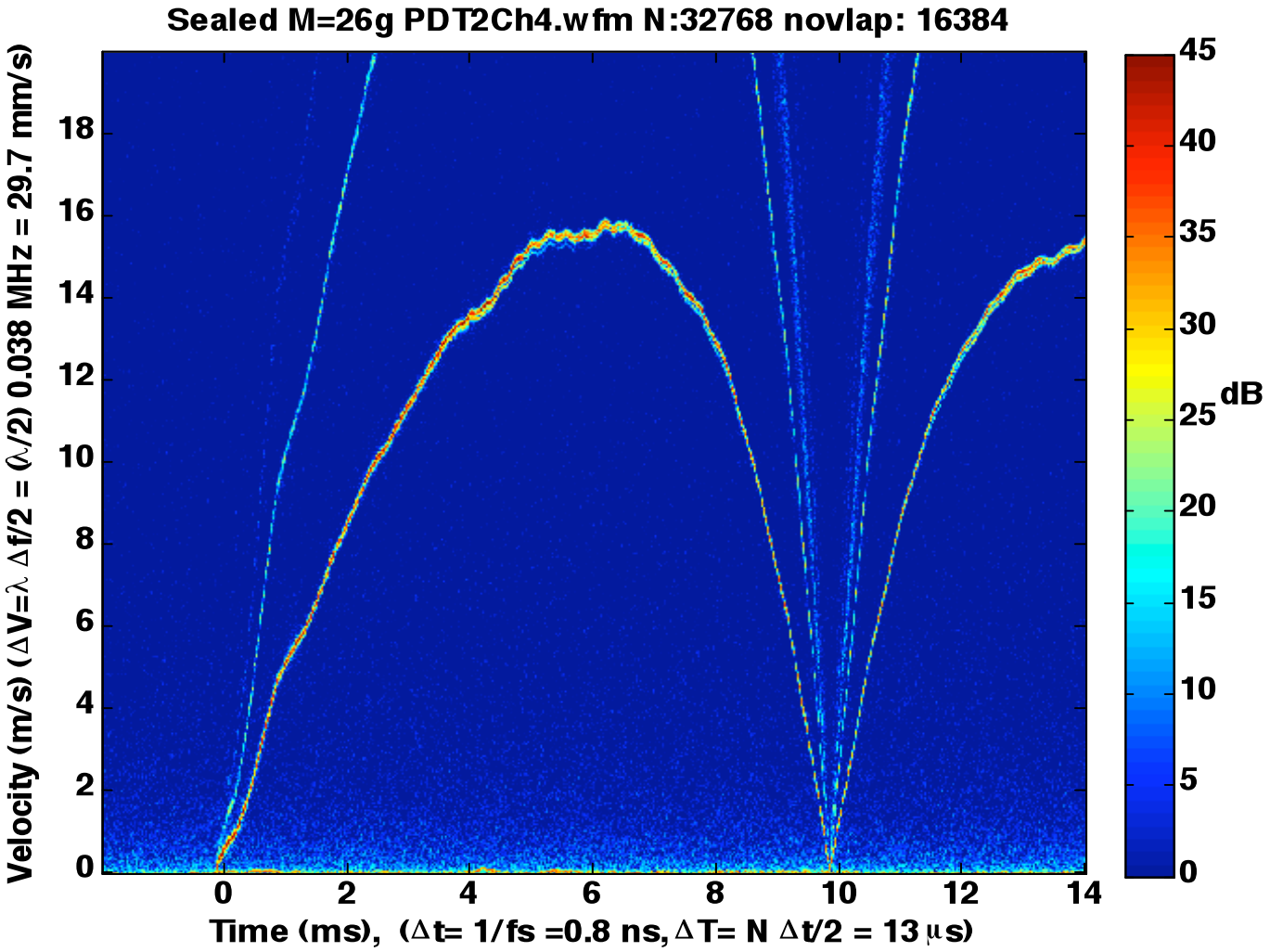
Tests 1-4 Back of *Sealed* PD Gauge



Test2: PDP gauge - PDV Analyses

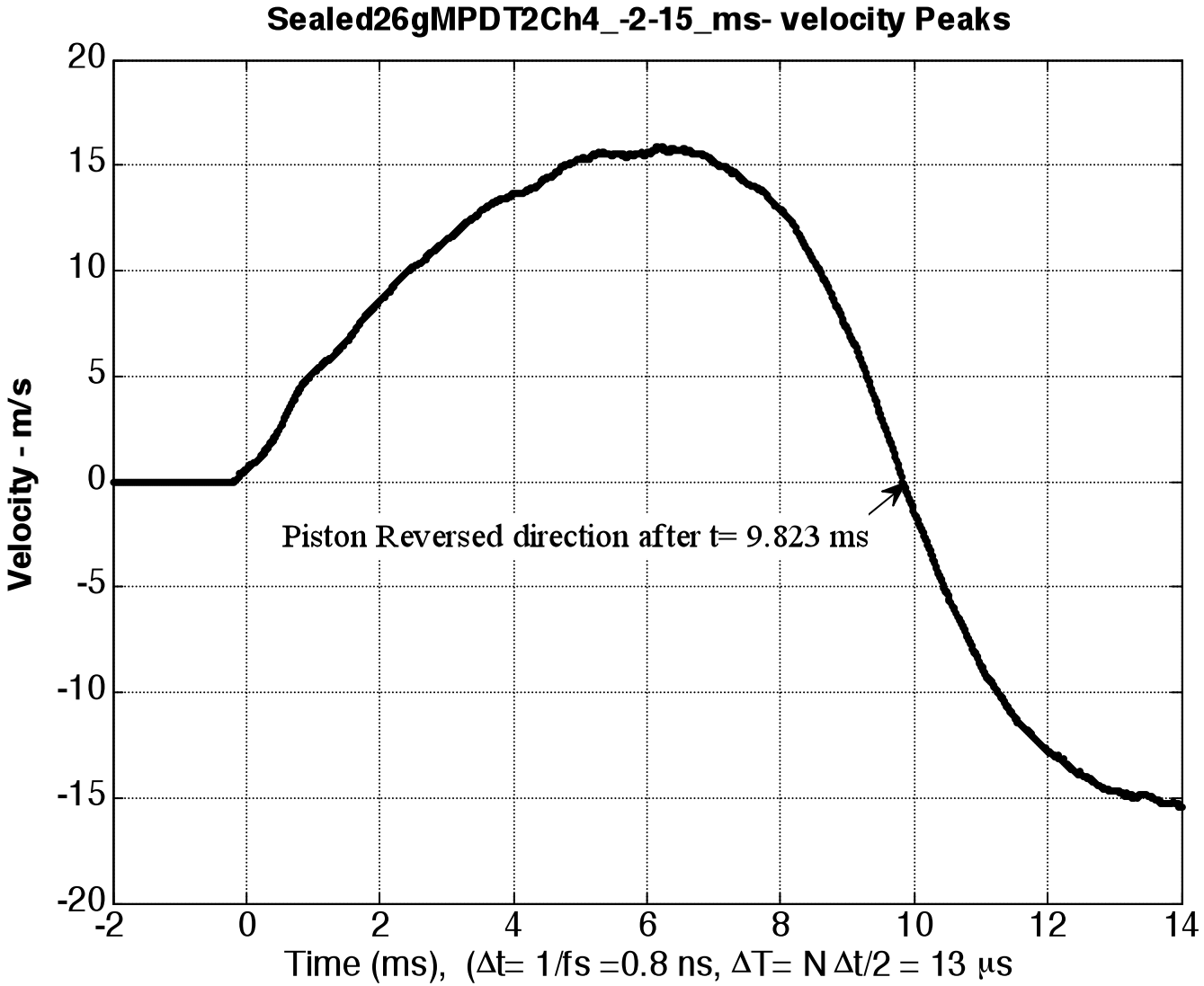
$$|V(t)| = \lambda_0 f(t)/2$$

$$= 775 \frac{\text{m/s}}{\text{MHz}} f$$



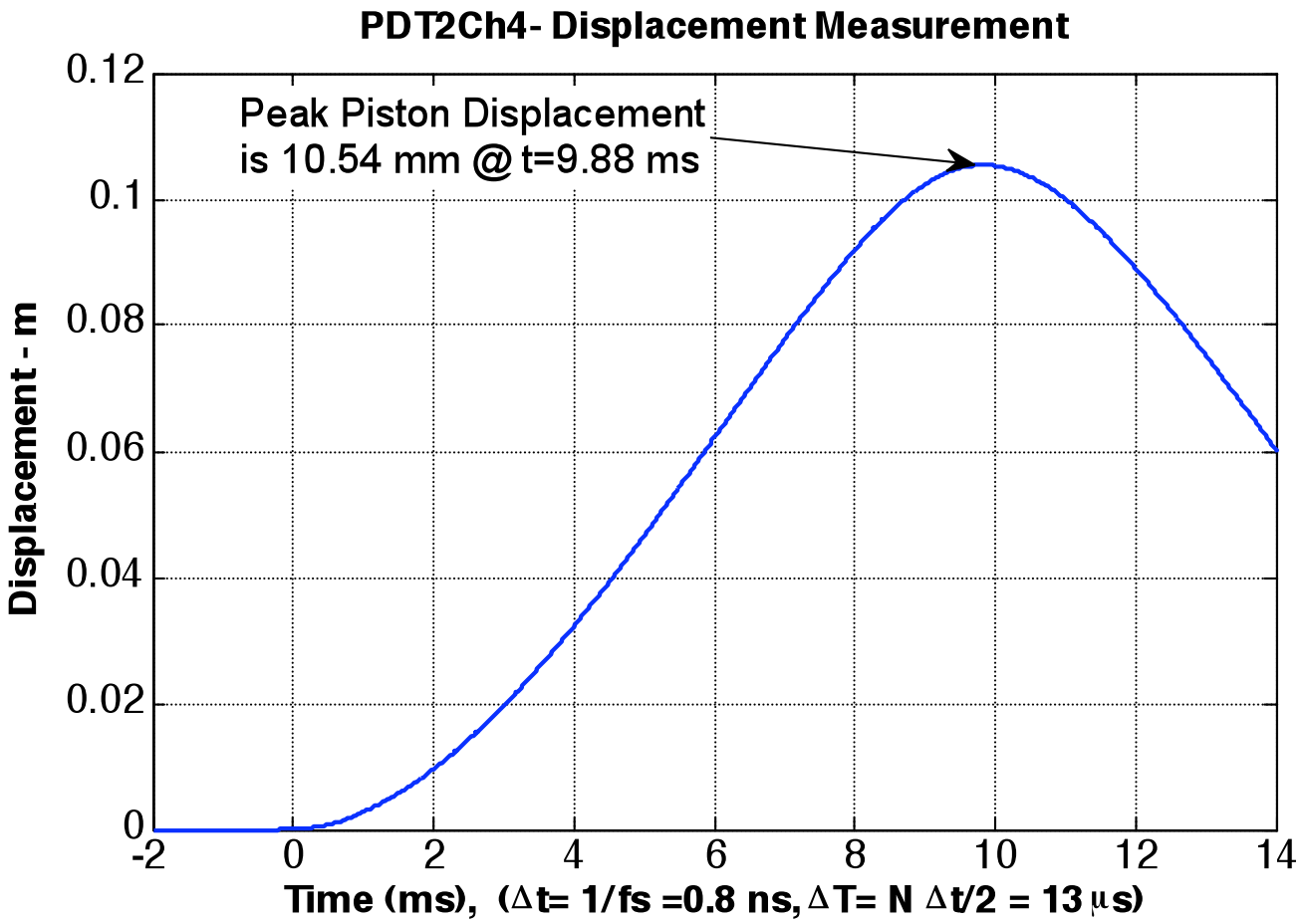
Test 2: L=11.1 cm, Al piston, m= 26 g

Test 2: Velocity V(t) – Peak of Spectrogram



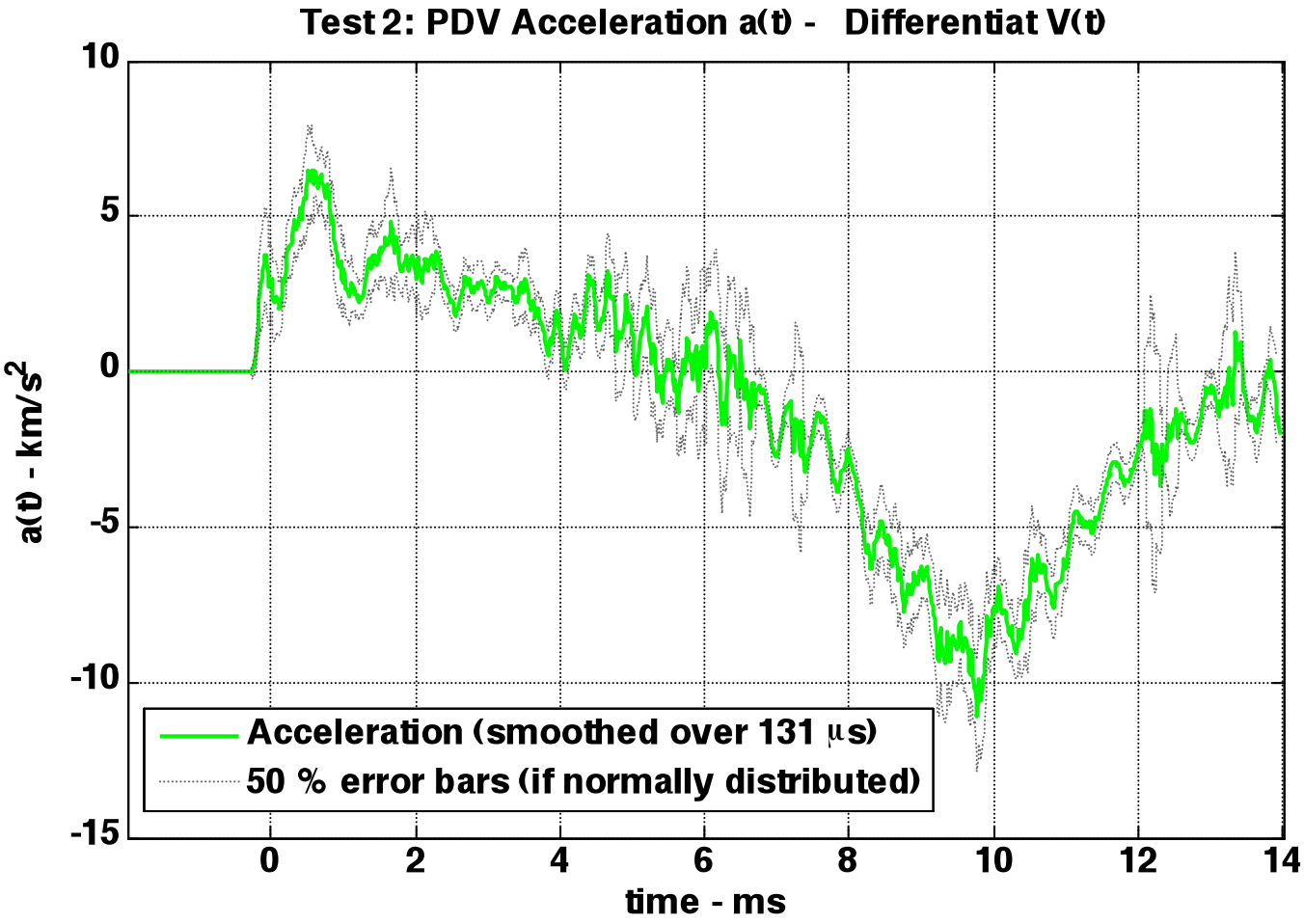
Test 2: L=11.1 cm, Al piston, m= 26 g

Test 2: Displacement



Test 2: L=11.1 cm, Al piston, m= 26 g

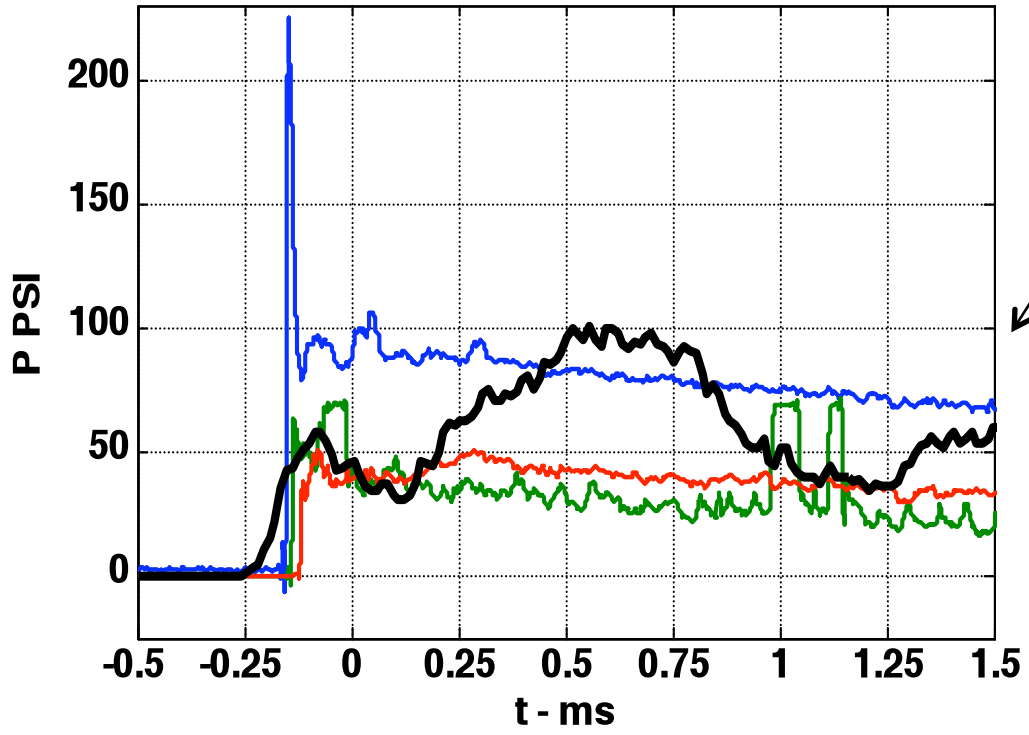
Test 2, Acceleration: differentiate* V(t)

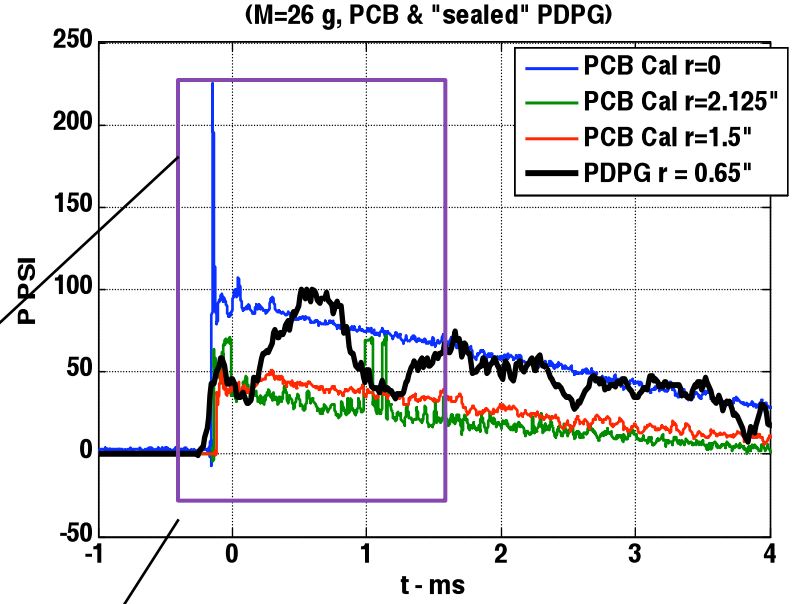


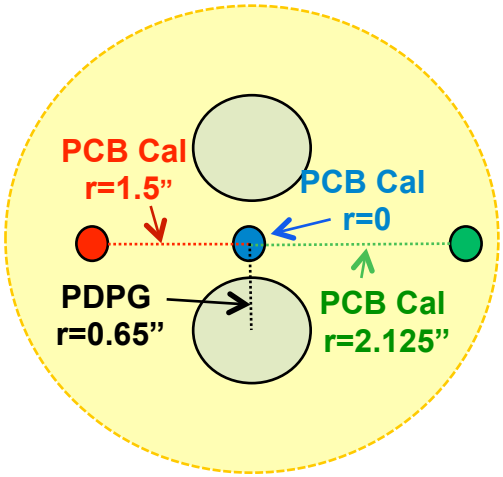
Test 2: L=11.1 cm, Al piston, m= 26 g

Test 2: Compare Pressures: Calibrated and PDPG

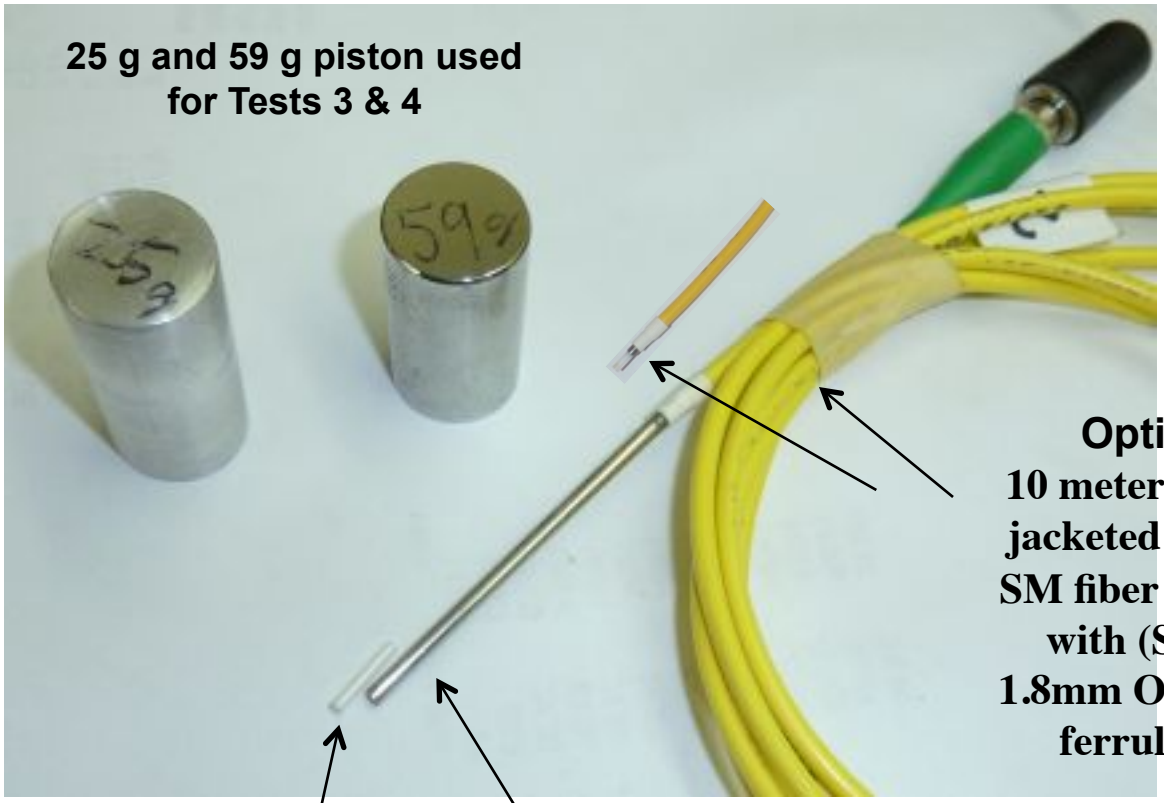
Test 2: m= 26 g Al piston, L=11.1 cm,







PDPG at Reduced Size



Optics pigtail probe:
10 meters long, 3mm OD loose jacketed, 9/125μ 1300/1550nm SM fiber patchcord, terminated with (SP) an 8° AR coated 1.8mm OD, 6 mm long zirconia ferrule & angle FC/APC connector

1.8 mm diameter, 89.6 mg zirconium slug

Hypodermic barrel

Acknowledgement Receipt

The USPTO has received your submission at **12:42:03** Eastern Time on **18-AUG-2010** .

$ 110 fee paid by e-Filer via *RAM* with Confirmation Number: **8654.**

eFiled Application Information

EFS ID	8241863
Application Number	61374710
Confirmation Number	6233
Title	SYSTEMS AND METHODS FOR PRESSURE MEASUREMENT USING OPTICAL SENSORS
First Named Inventor	Scott Levinson
Customer Number or Correspondence Address	32794
Filed By	Mary Jo Bertani
Attorney Docket Number	5711-FIS
Filing Date	
Receipt Date	18-AUG-2010
Application Type	Provisional

Application Details

Submitted Files	Page Count	Document Description	File Size	Warnings
5711-FIS-ApplicationAsFiled.pdf	23		370265 bytes	PASS

Document Description	Page Start	Page End
Provisional Cover Sheet (SB16)	1	2
Specification	3	12
Claims	13	17
Abstract	18	18
Drawings-only black and white line drawings	19	23

fee-info.pdf	2	Fee Worksheet (PTO-875)	29263 bytes	PASS

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Future plans

- **Additional calibration experiments–**
- **Develop software for signal analysis that includes internal pressure correction, Acoustic effects ringing, and other PDPG imperfections**
- **Investigate use of special pistons to optimize frequency response and recording time.**
- **Identify new, less expensive PDV instruments & technologies.**

  Example: ***National Instruments, new NI PXIe-4844 optical sensor interrogator*** ***http://zone.ni.com/devzone/cda/pub/p/id/1158***

***Many useful presentations are available for download at the international PDV workshop at IAT/Austin TX:**
http://www.iat.utexas.edu/pdv/
under: Abstracts and Presentations

Appendix Slides

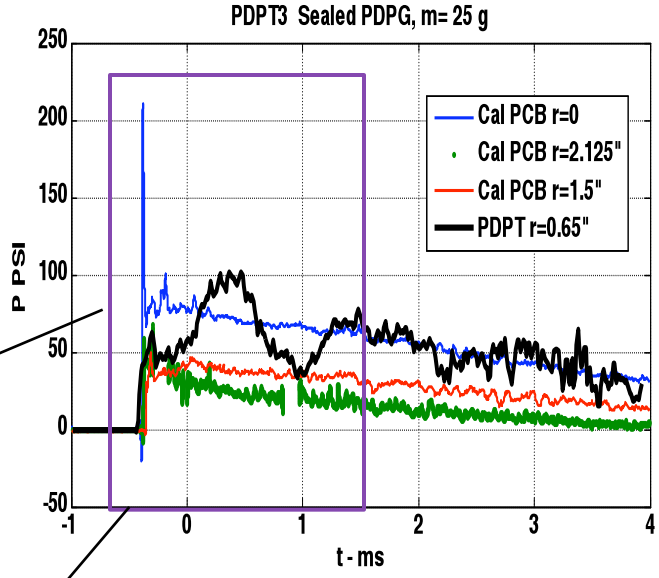
Conclusion

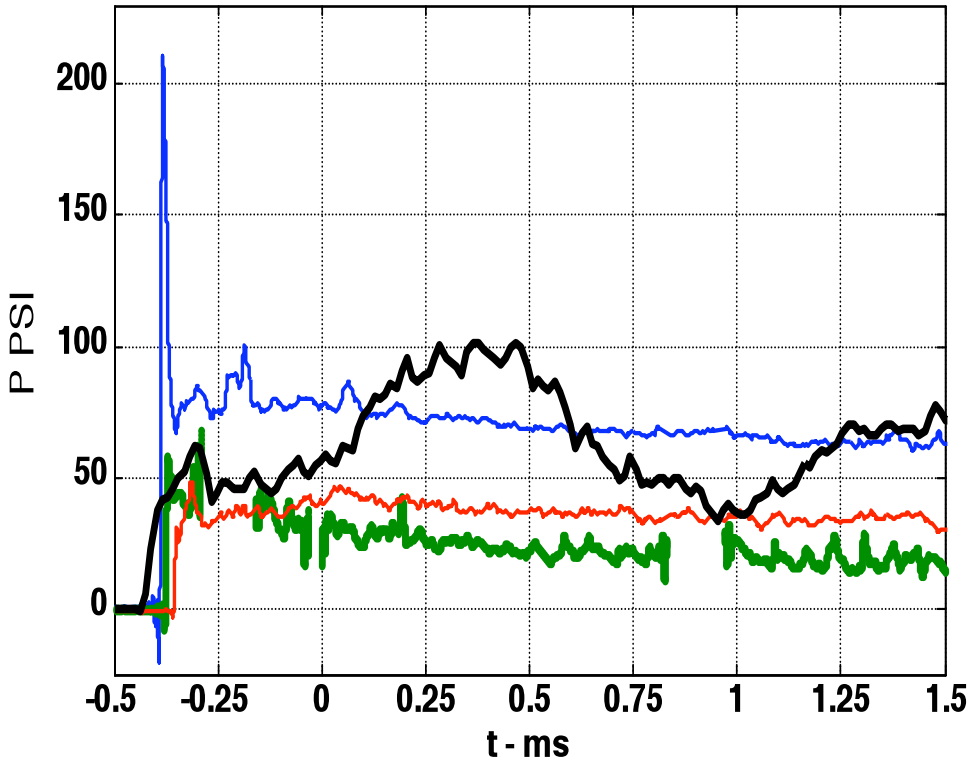
- **We have successfully demonstrated proof of principal of the PDPG.**

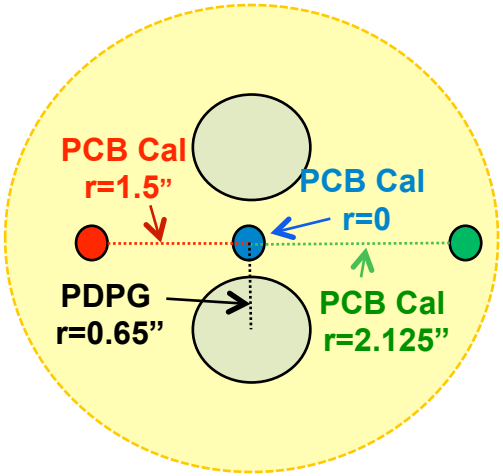
- **With further development, we expect the PDPG to become an inexpensive, robust, and effectively sacrificial tool that will grant access to environments previously considered impractical.**

Test 3: Compare Pressures: Calibrated and PDPG

Test 3: m= 25 g, Al piston, L =11.1 cm,

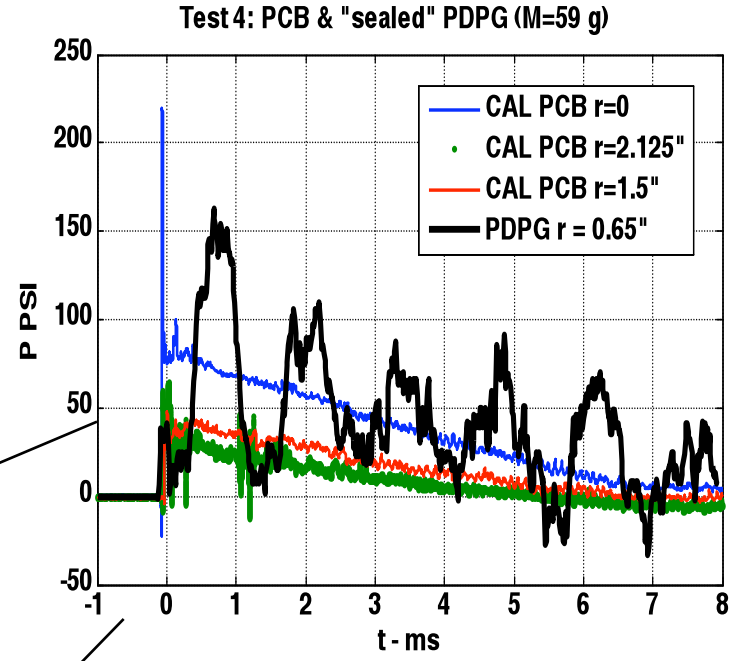


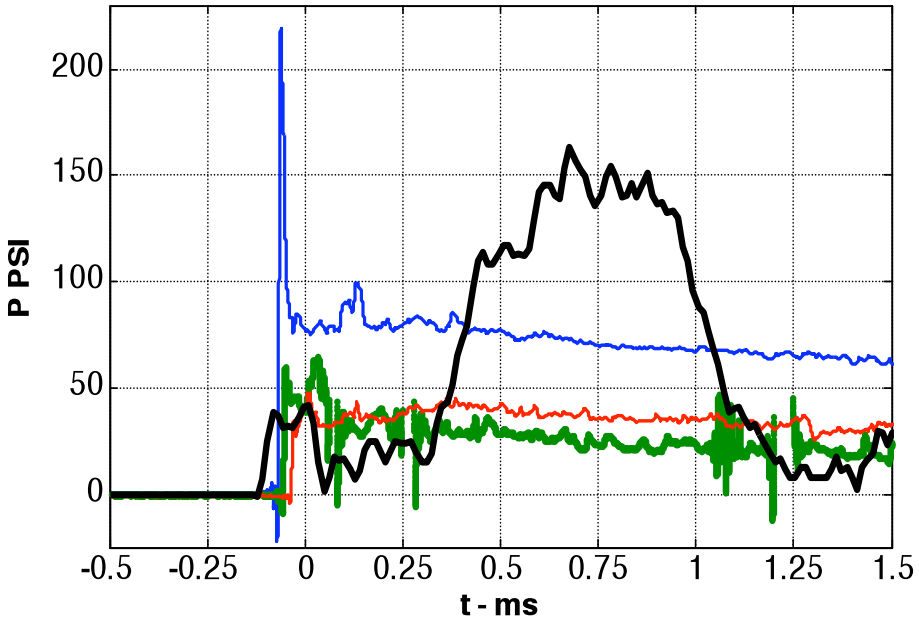


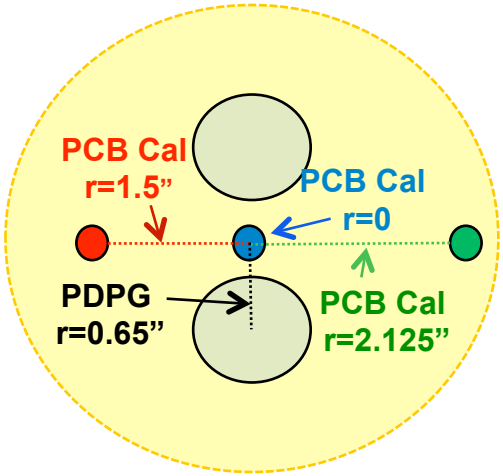


Test 4: Compare Pressures: Calibrated and PDPG

- Test 4: m= 59 g Steel piston,
- L =11.7 cm,







Test 1

Unsealed PD gauge
Ch 3
Aluminum: m=21 g
ρ=2.63 g/cm^3

Sealed PD gauge
Ch 4
Steel: m=95 g
ρ=7.768 g/cm^3

V=6.132 m/s **V*m= 130 g m/s**

V=1.219 m/s **V*m= 115 g m/s**

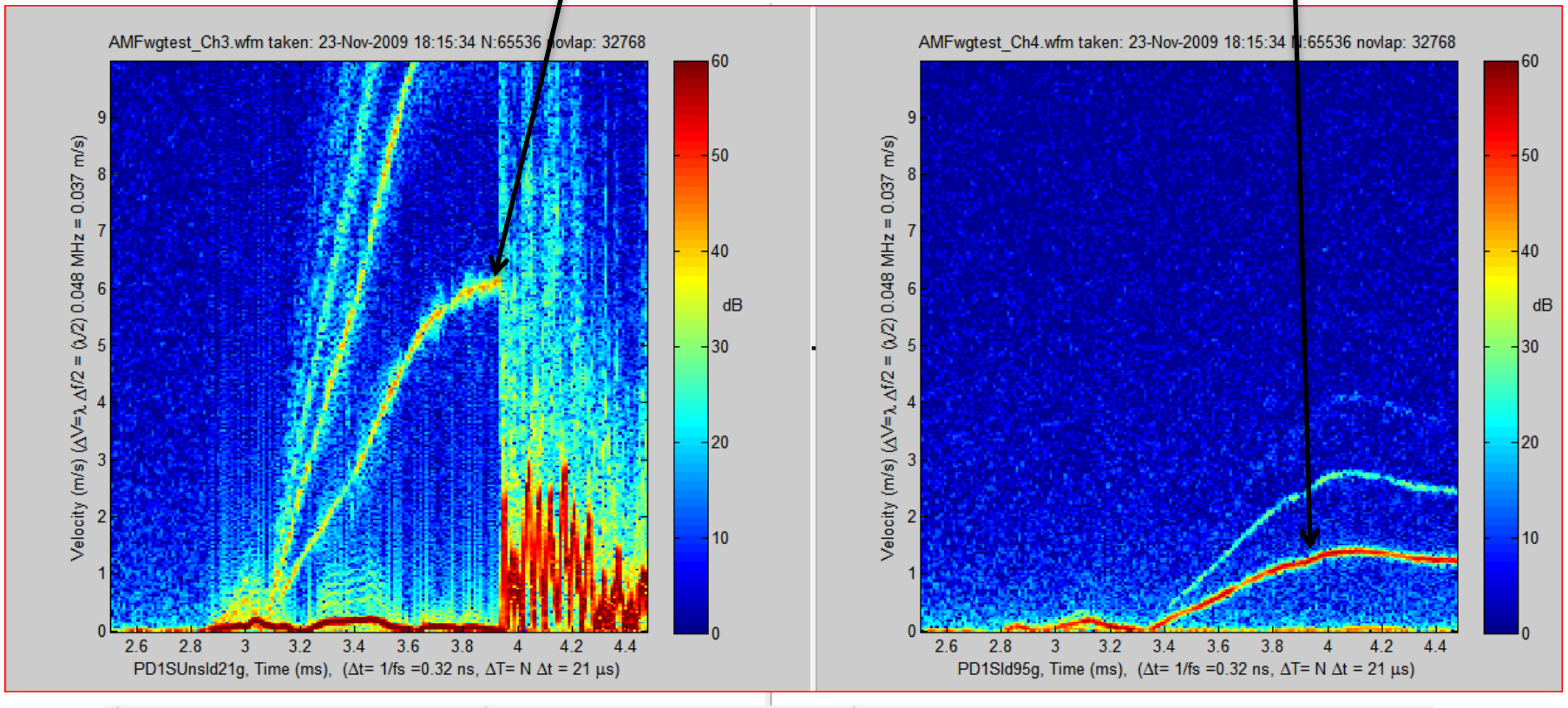
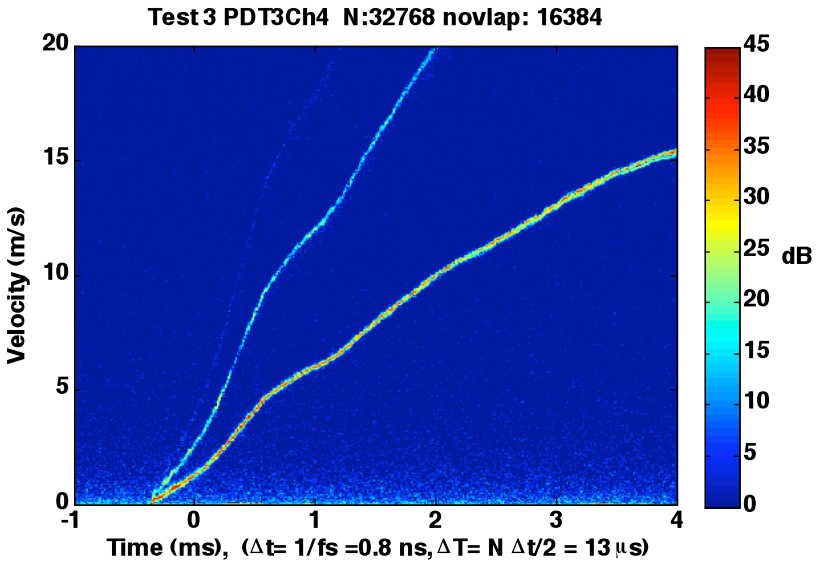
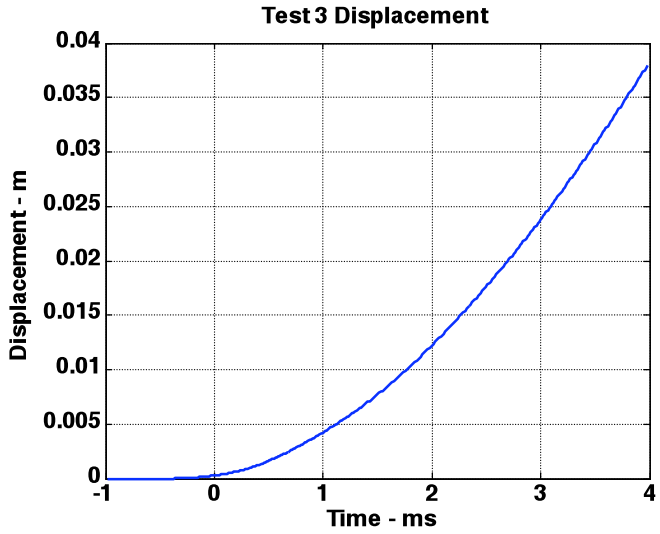
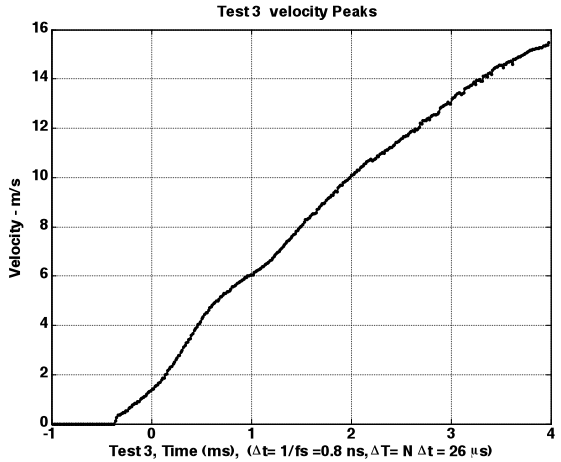


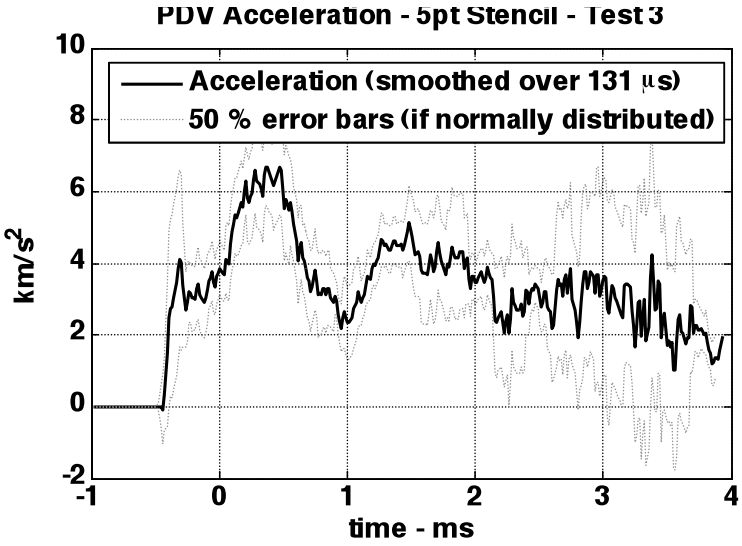
Figure 2: testAMFwgtest_Ch3_0-2... × Figure 1: testAMFwgtest_Ch4_0-2... ×

PDV Analyses Test 3 m=25 g

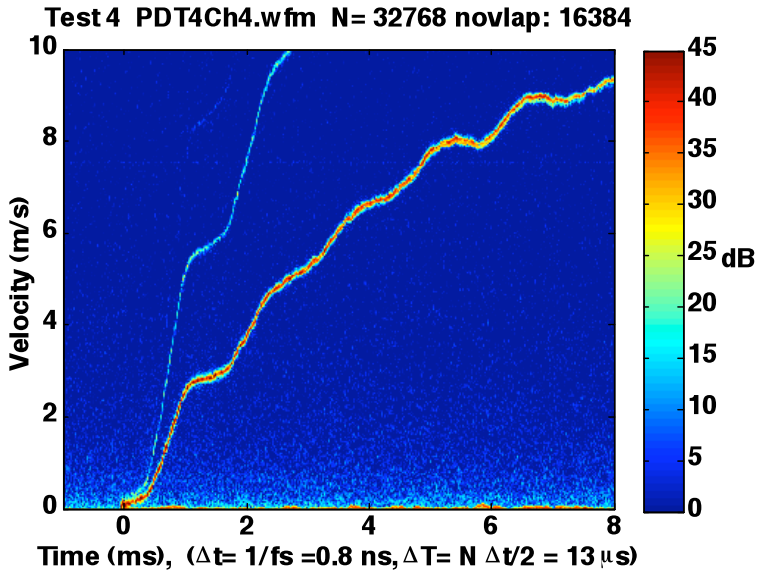


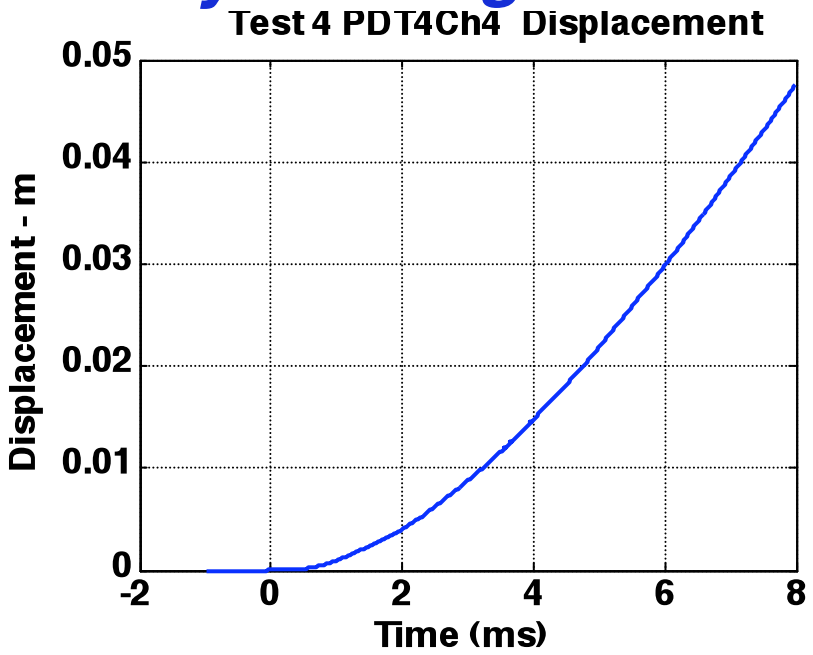


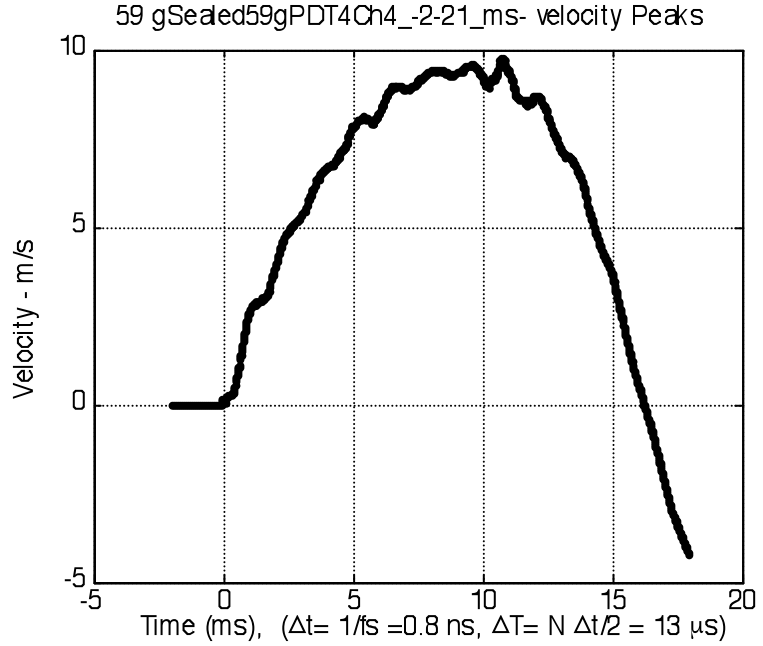


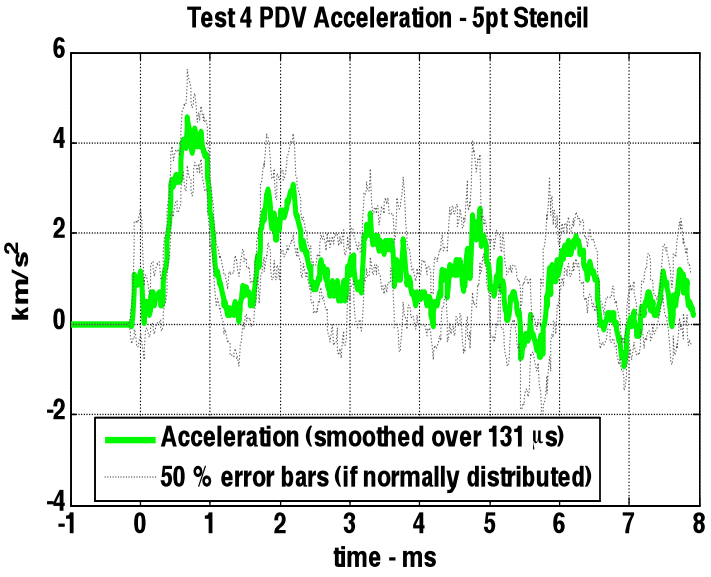


Test 4 - PDV Analyses 59 g









Pressure spikes on Cal gauge at r= 2.125